HIRSCH

The American Lung Fluke, Paragonimus Kellicotti

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THE AMERICAN LUNG FLUKE, PARAGONIMUS KELLICOTTI

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

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Historical Introduction.

The earliest record of a lung fluke in mammals was published by Kerbert in 1878. During an autopsy held in the zoological gardens at Amsterdam, Holland September 1877 parasites were found in the lungs of a tiger, and were sent by the director, Westerman, to Kerbert who determined the undescribed trematodes, and named them Distomum Westermanii. Three years later Kerbert received specimens through Bolau from the lungs of a tiger that had died in the zoological gardens at Hamburg, Germany. Upon this material he completed an extensive morphological study (Kerbert , 1881).

The first knowledge regarding a lung fluke in man comes through Baelz from Japan. Baelz in 1878 noted the condition resulting from the parasitic infection as distinct from tuberculosis with which it had been confused. He sent a considerable quantity of sputum to Leuckart for investigation, describing the ova contained therein as psorosperms. Before Baelz received Leuckart's diagnosis, he himself had reached the conclusion that the supposedly psorosperms were really distomum eggs. He reported his findings to Manson who had made a similar observation in Amoy, and shortly afterwards secured a single specimen in very poor condition which had been found by Finger in the bronchus of a man from Formosa, where the infection was shown later to be widely prevalent. This specimen was sent to Cobbold, in London, who in 1880 is said to have named it Distomum Fingeri. Shortly after this Baelz secured specimens of the parasite in Japan, and gave according to Leuckart a brief specific diagnosis of the new form. Baelz sent material to Leuckart who in 1889 completed a study of the Asiatic lung fluke, and after comparing it with Kerbert's specimens of Distomum Westermanii, concluded that these parasites were ident-

ical. Leuckart does not agree with Kerbert in every particular, but considers the minor differences unimportant, a conclusion which now seems open to question.

Since the first recognition of this parasite in Japan, Korea, and Formosa, its occurrence in man in these countries has been reported very frequently. Musgrave in 1907 reported the lung fluke in seventeen human hosts from the Philippine Islands. Of these one was a Chinaman, two were Japanese, and the others were native Philipinos.

The first record of the lung fluke in America was published by Ward (1893) who found the parasite in a cat at Ann Arbor, Michigan. Kellicott (1894) and Ward (1895) report a single occurrence in a dog from Columbus,Ohio. In1890 Stiles and Hassell reported the lung fluke from hogs killed at the Cincinnati abattoirs. Very recently the parasite has been found again in cats, one in Minneapolis, Minn. by Nickerson, and by four from Wauwatosa, Wisconsin by Hirsch. Null (1910) says that this parasite occurs in dogs and cats from the Oriental quarters of San Francisco, but gives no authority for the statement.

Until 1904 the only hosts reported from America were the dog, cat, and hog; in that year Mackenzie recorded the lung fluke in a Japanese fisherman along the Columbia River. Recently (1910) Null records another occurrence in a Korean from Seattle, Wash. These hosts undoubtedly acquired the infection in their native countries.

Name of the Parasite.

Originally the lung flukes from mammals were included under the genus Distoma. Braun in 1899 proposed the generic name Paragonimus for this group of parasites. This name is now accepted. At the time it was proposed all the lung flukes were considered identical, and included within the single species Paragonimus Westermanii. Ward in 1903 pointed out the differences in measurements given for the egg of Paragonimus Westermanii by various investigators. "It is difficult," he states, "to believe that all records can be correct as they stand, unless some other species is concerned." Several years later, Ward (1908) again reviewed these records, and with regard not only to the ova but to the structural elements as well, expressed his conviction that the American form which he described originally and identified as Paragonimus Westermanii is undoubtedly a distinct though closely related species. Looss (1905) also believed the identity of these lung flukes improbable, even though complete evidence for this view had not been presented.

The specific name Paragonimus Westermanii was applied originally to designate the lung fluke found in the tiger. Ward in 1908 named the American lung fluke Paragonimus Kellicotti. After mentioning the similarity in the various measurements of Japanese material made by different observers, he added that the Asiatic form may be after all a distinct species from Kerbert's tiger parasite with which the Japanese measurements do not agree. Ward (1908) further stated that the Asiatic lung fluke will not need a new name, but will probably go back properly to take one of the earlier names used by investigators of the human parasite in Japan. Following this suggestion the Asiatic parasite which was named Distomum

Fingeri, Cobbold (1880) should now be known as Paragonimus Fingeri (Cobbold).

The present study of Paragonimus Kellicotti was taken up with the purpose of inquiring into the morphology of the American lung fluke. This work was supplemented by such a comparison with Paragonimus Westermanii and Paragonimus Fingeri as the available material of the latter two species permitted. Three co-type specimens of Paragonimus Westermanii were obtained from Kerbert and are in Professor Ward's collection. Several specimens of Paragonimus Fingeri (10:78) are also in this collection from Uchida, Tokyo, Japan. These were very kindly placed at my disposal for study by Professor Ward.

Methods and Material.

The material used in the study of Paragonimus Kellicotti was obtained alive from infected hog lungs. The parasites were fatigued by shaking in normal saline solution, and then killed by adding a saturated corrosive sublimate solution containing 1% of glacial acetic acid. The tissues were fixed by allowing the corrosive-acetic solution to act for several hours, after which the specimens were passed through the various grades of alcohol up to 70%. Here they were transferred into a 70% alcoholic solution of iodine in order to remove the corrosive sublimate, the excess of iodine being subsequently removed by washing in 70% alcohol. Such specimens as were used for sectioning were stained in toto for about 12 hours in a 50% alcoholic solution of Ehrlich's acid haematoxylin. The excess of the stain was removed by washing in 50% alcohol, after which the material was passed through the various grades into absolute alcohol, about 5 hours being spent in each. At this point they were cleared in cedar oil, and then infiltrated with paraffin. Two grades of paraffin were used in this process, and the time spent in each was from 5 - 7 hours. This rather long period for infiltration seemed to be necessary for the best results. The final imbedding was made in fresh hard paraffin. All of the sections were cut 15 microns in thickness. The measurements of the entire body were made under a ×8 dissecting lens. The other measurements were made using an ocular micrometer on a compound microscope.

Description.

Paragonimus Kellicotti has a somewhat elongated, elliptical form in dorsal aspect (Pl.II fig.23). The dorsum is strongly arched, the highest point being somewhat anterior to the middle portion of the body, while the ventral surface is flattened. The anterior end rounds off gradually, but the posterior extremity is attenuated, and sharply curved. The range in size of five parasites is given in comparison with Paragonimus Ringeri and Paragonimus Westermanii.

Species	Host	Length=mm Av.	Max.	Min.	Width=mm Av.	Max.	Min.	Thickness=mm Av.	Max.	Min.	
P.Kellicotti	Hog	9.8	11.0	8.5	3.1	3.5	3.0	2.6	3.2	2.2	Hirsch
P.Westermanii	Tiger		9.0	7.0		6.0	4.0		4.0	2.0	Kerbert
P.Ringeri	Man		10.0	8.0		6.0	5.0				Leuckart
P.Ringeri	Man	9.6	13.0	7.1	5.0	7.5	5.0	3.7	4.0	3.5	Katsurada

From these figures may be noticed that there is considerable variation in the size of the different parasites. Taken in composite sketch, however, a description of the American form emphasizes its very much elongated, relatively slender structure, which is in striking contrast with Leuckart·s Paragonimus Ringeri, and Kerbert·s Paragonimus Westermanii, both of which are oval-shaped, thicker, and broader parasites. Among the numerous specimens of Paragonimus Kellicotti in Professor Ward·s collection, there is one which exceeds the dimensions given above. This particular specimen is such a striking exception as to justify considering it not representative of the group. The dimensions for this parasite are 8.7 mm in length, 6.3 mm in breadth, and 4.5mm in thickness.

The oral sucker is found at the anterior extremity (Pl.II fig.23) directed towards the ventral surface at an angle of about 45°, while the acetabulum lies on the same surface in the median line slightly anterior

to the center of the body. In ten specimens these suckers average respectively 0.75 mm and 0.83mm in diameter. The two suckers of Paragonimus Westermanii are of about equal size, 0.78 mm in diameter according to Kerbert, while those of Paragonimus Ringeri are unequal, and smaller, the oral sucker being 0.53mm in diameter and the acetabulum 0.6 mm - at most 0.75 mm according to Leuckart.

The genital pore in Paragonimus Kellicotti lies just behind the acetabulum, medial or a little to the right or the left. The position of the genital pore as given by Stiles for this species is the same.

The cuticula covering the entire body is relatively thick, and is armed with spines (Pl. II fig. 25). The thickness of this structure, however, is not uniform over the entire body. Around the suckers it may be 0.005mm thick, while over the posterior extremity it may be 0.048 mm. There is often also a distinct difference in the appearance of this layer. Sometimes it seems perfectly homogeneous, but in other places it appears as if made up of two distinct layers, an outer more dense and less refractive, and an inner vertically striated rather clear, or highly refractive with numerous coarse granules. As might be expected, the cuticula shows no cellular structure, but is sharply marked from the underlying muscles by a distinct basement membrane.

The spines (Pl. II Figs. 30-39) of Paragonimus Kellicotti which lie in irregular circular rows over the body are set firmly in the cuticula with their free ends directed posteriorly. They extend entirely through the cuticula, and sometimes into the body musculature beneath. Structurally, the spines are thin chisel-shaped scales, in general several times as long as wide. The surface directed away from the body is slightly convex, while that directed towards the body is correspondingly concave. The free

end is rather deeply serrated into a number of very sharp teeth. These certainly aid the parasite materially in effecting its movements, and in maintaining its position in the tissues of the host. The basal end of the spines is broader and thicker (0.005 - 0.010mm) than the tip, often appearing cleft so as to show in cross-section groups of closely aggregated oval or irregularly-shaped chitinous bodies.

There is a distinct difference in the distribution and size of the spines (Pl.II Fig.31-39). The suckers are entirely devoid of these structures, while the cuticula closely surrounding shows the transition stages between the non-spined and the spined condition. This holds true especially for the region surrounding the acetabulum. Here the body for a small distance around the sucker may be entirely free from spines. When they appear, they are few in number but very sharp and even decidedly hooked. Around the oral sucker the spines are short with broad bases and sharp tips, a condition which is soon replaced by the larger spines with broad serrated tips. The spines are set relatively thicker over the anterior half of the body than over the posterior. The cuticula on the dorsal surface just behind the oral sucker, and on the ventral surface between the suckers and just behind the acetabulum is especially well armed. The spines over the dorsal surface show little variation except in number and in length. On the ventral surface the greatest variation occurs around the suckers. This divergence, however, is not one from the characteristic type, but rather is a gradual diminution in size. The spines on this surface of the body are perhaps shorter and broader than over the dorsum.

Spine Measurements of Paragonimus Kellicotti.

Ventral Surface.

Oral Sucker	Length	0.010 mm	0.005 - 0.008 mm apart.
	Base	0.005 mm	
	Tip	0.000 mm	
Between Suckers	Length	0.046 mm	0.013 - 0.026 mm apart.
	Base	0.013 mm	
	Tip	0.013 mm	
Acetabular region	Length	0.010-0.020mm	0.030 mm - variable.
	Base	0.005 mm	
	Tip	0.000 mm	
Between Acet. and Post.	Length	0.031 mm	0.026 mm apart.
	Base	0.013 mm	
	Tip	0.008 mm	
Between Acet. and Post.	Length	0.039 mm	0.013-0.026 mm apart.
	Base	0.023 mm	
	Tip	0.021 mm	
Posterior Extremity	Length	0.036 mm	0.026 - 0.047 mm apart.
	Base	0.015 mm	
	Tip	0.008 mm	

Dorsal Surface.

Anterior Extremity	Length	0.031 mm	0.008 - 0.012 mm apart.
	Base	0.010 mm	
	Tip	0.008 mm	
Anterior 1/4	Length	0.034 mm	0.012 - 0.026 mm apart.
	Base	0.010 mm	
	Tip	0.008 mm	
Middle	Length	0.044 mm	0.015 - 0.026 mm apart.
	Base	0.010 mm	
	Tip	0.008 mm	
Posterior 1/4	Length	0.040 mm	0.026 - 0.036 mm apart.
	Base	0.010 mm	
	Tip	0.008 mm 0.010 mm	

Posterior Extremity	Length	0.026 mm	0.012-0.026 mm apart.
	Base	0.010 mm	
	Tip	0.008 mm	

The dimensions of the spines of Paragonimus Westermanii as given by Kerbert has elicited considerable comment, for he reports the largest spines 0.018 mm long by 0.002 mm broad at the base, and the others 0.010 mm long. He describes the spines as lancet-shaped. Kerbert's figure shows the aboral pole of the parasite, and the surface for a short distance around the oral sucker entirely devoid of spines. Upon re-examining the co-type specimens of Paragonimus Westermanii in Professor Ward's collection these statements were not found to hold true. The spines are indeed lancet-shaped, but are considerably longer than Kerbert's dimensions indicate. They are fully as long as those in the cuticula of Paragonimus Kellicotti being 0.047 - 0.049 mm long by 0.005- 0.010mm broad at the base. In addition, spines cover the entire body, excepting the suckers as in Paragonimus Kellicotti. Leuckart gives the measurements for the longest spines of Paragonimus Ringeri as 0.06 mm with a base 0.014 mm broad. These dimensions approximate the condition revealed in Paragonimus Kellicotti.

From the foregoing statements it is evident that the spinesof Paragonimus Westermanii depart radically from those of Paragonimus Ringeri and Paragonimus Kellicotti. In the former species they are lancet-shaped, but in the latter two they are broad and chisel-shaped. While this is a very striking characteristic, the spine arrangement is even more distinctive. The spines in Paragonimus Westermanii lie rather sparsely scattered in more or less incomplete circular rows (Pl.II fig.28). Their free ends extend very far beyond the cuticula, giving the parasite a thorny appearance. The condition in Paragonimus Ringeri is different, Over certain

parts of the body, especially on the ventral surface behind the acetabulum the spines are short with broad bases and tips. Here they are set very closely together, at times in almost continuous circular rows. Along the side of the body the spines are slender with sharp free ends. These differences in shape are very clear, but not nearly so striking as is the spine arrangement (Pl.II fig.29). In Paragonimus Westermanii the spines are sparsely scattered, and occur singly. In Paragonimus Ringeri the spines are characteristically arranged in groups, which occur very frequently and in certain parts of the body form almost continuous circular rows. While the shape of the individual spines in Paragonimus Ringeri is subject to variation, in fact offering a transition series between Paragonimus Westermanii and Paragonimus Kellicotti, the group arrangement affords a striking and constant differentiation (Pl.II figs27-29. The spines of Paragonimus Kellicotti are of one general type, chisel-shaped, with distinctly serrated or saw-toothed free extremities. There is, to be sure, a variation in their length, but in general the characteristic features of this type of spine are retained throughout. The study of the spines of Paragonimus Kellicotti involved their examination over the entire body of the parasite, and in no place was there any marked divergence, and no where did they occur other than singly. While the substance of the comparison was made upon material taken from the hog, further data were obtained by examining a piece of the cuticula from a parasite removed from the lungs of a cat. The shape of these spines as well as their arrangement was the same (Pl.II fig. 30), the only difference noted was that they were somewhat longer (0.078 mm), and their free ends more serrated. The difference in the spines of the three species may be briefly tabulated as follows:-

	P.Westermanii	P.Ringeri	P.Kellicotti.
Shape	Lancet-shaped	Chisel to Lancet	Chisel-shaped
Distrib.	Sparsely, somewhat irregularly, singly.	Circular rows, in groups	Circular rows, singly.

The body musculature lying just beneath the cuticula, consists essentially of two distinct layers, an outer circular and an inner longitudinal. The fibers of the circular layer are continuous in their passage around the body, but this cannot be said of the longitudinal layer. Beneath these layers is a third oblique layer. The fibers of this pass diagonally around the body in two sets of parallel bands that lie at right angles to each other. The individual fibers are well developed, and form a distinct lattice-like mesh. Another group of muscles having largely a dorso-ventral direction passes through the body proper. These are the parenchymatous muscles. Their regular vertical distribution is somewhat disturbed by the internal organs.

Beneath the inner oblique muscle layer lie the sub-cuticular cells. These are relatively large with one or more nuclei, and send long processes up through the muscle layers to the basement layer of the cuticula.

The opening leading from the oral sucker into the pharynx is about 0.050-0.075 mm in diameter. This becomes somewhat larger toward the outer margin of the sucker. In sectional view this opening appears wedge-shaped. It is continuous with a thin lamella which forms a small pocket, the pre-pharynx, and serves to unite the pharynx with the sucker. (Pl. I fig 2)

The entrance into the pharynx is provided with four lip-shaped protuberances which effectively close the canal during contraction. The two which lie laterally are larger than those bounding the tube dorsally and ventrally, thus making the entrance into the pharynx appear much like

a vertical slit. The pharynx is spherical in shape, about 0.4375 mm in diameter. Its walls are heavily musculatured, and the canal itself is limited to a narrow vertical slit. The inner lining of the pharynx consists of a thin layer of the cuticula 0.010-0.020mm thick. Toward the union with the oesophagus the opening through the pharynx widens considerably.

The oesophagus in nearly circular in outline (Pl.I fig.), and about 0.21-0.255mm long. The anterior part of the alimentary canal is directed towards the dorsal wall, but not very acutely. With the junction of the oesophagus and the pharynx this direction is continued, but slightly more abrupt. At first the oesophagus is about 0.080mm in diameter, but towards its branching this dimension decreases slightly and then increases again to 0.160 or even 0.175 mm. The thickness of the wall varies in this short distance from about 0.012mm near the pharynx to 0.050mm somewhat nearer the bifurcation. This difference necessarily causes the inner lumen to vary inversely. Such relations as have been described are subject to variations due to the contraction of these parts. Structurally the oesophagus is relatively simple, consisting of an inner homogeneous layer, often thrown up in folds, and an outer well developed muscular layer. The latter is made up essentially of the inner circular fibers, while the outer longitudinal surrounds the wall in relatively heavy parallel bands. This portion of the alimentary canal is surrounded by well developed glandular cells whose ducts open into the oesophagus, in all probability furnishing a digestive secretion. (Pl.I fig.)

The two lateral branches of the oesophagus are 0.175-0.255 mm long, and are sharply differentiated from the intestinal caeca by several distinct characters. The intestinal caeca immediately have a diameter of 0.315 mm, whereas the oesophageal branches are only 0.050 mm in this

dimension. More generally speaking there is in this region a sudden increase in the diameter of the caeca of about four or five times that of the oesophageal branches. In addition, the intestinal epithelium is characterized by tall columnar cells (Pl.I fig.9) which contrasts strikingly with the non-cellular lining of the branches of the oesophagus.

After the bifurcation of the oesophagus into the two lateral branches, these ascend rather rapidly toward the outer margins of the body, and come to lie close under the vitellaria, but not widely separated from each other. This relation is apparent in as much as the body of Paragonimus Kellicotti is not broad, but attenuate. After its short transverse passage, each of the intestinal caeca passes backward toward the posterior extremity of the body, where they end blindly, one on each side and quite close together. The termination of each canal takes place at about the same level, although a slight variation occurs, and sometimes the one will end a little sooner than the other. In lateral view the caeca show three large loops arching toward the dorsal surface. Between these, secondary loops appear. The three principal loops, while at first directed dorsally, ultimately curve with the body wall, and when viewed from above are turned toward the median line. At these points the intestinal caeca approach each other very closely, in fact the space between the most anteriorly located loops is very small.(Pl.I figs7,12-14). With this relation in mind it is evident that the digestive system is very extensive, and that each of the caeca if drawn out straight would be nearly twice the length of the entire body. There are also places where the intestine widens out considerably and shows distinct enlargements. In these places the diameter may become 0.68mm, while toward the posterior extremity it is 0.225mm.

The anatomical relationship of the alimentary canal in Paragonimus

Westermanii and Paragonimus Ringeri presents some characteristic differences when compared with Paragonimus Kellicotti. In Paragonimus Westermanii the pharynx averages 0.5 mm long by 0.3mm broad according to Kerbert. It is then not a spherical structure as may be inferred from these dimensions, and from Kerbert·s figure. The pharynx of Paragonimus Ringeri according to Leuckart is spherical 0.3mm in diameter. The oesophagus (Kerbert) in Paragonimus Westermanii is also shorter, being 0.14mm long as compared with P. Ringeri which is 0.20mm long according to Leuckart. The relation of the intestinal caeca is a prominent difference. Kerbert says for this condition in Paragonimus Westermanii that the intestinal caeca after the bifurcation of the oesophagus pass posteriorly parallel with the surface of the body. They reach to the posterior extremity of the body, and then end blindly. He gives the length of the caeca at about 8mm, or approximately the length of the entire body. Such a simple relation does not exist in Paragonimus Kellicotti nor in Paragonimus Ringeri. Leuckart shows both in his description and by his sketches that the intestinal caeca of Paragonimus Ringeri are complicated by a number of loops and turns just as they are in Paragonimus Kellicotti. But this point must be born in mind; namely, that the latter parasite is attenuate and slender. The intestinal caeca in this form do not lie very widely separated from each other, and where the major loops arch over the body towards the median dorsal line only a very small space intervenes.

	P.Westermanii	P.Ringeri	P.Kellicotti
Pharynx	0.3mm × 0.5mm	0.3mm × 0.3mm	0.44mm × 0.44mm
Oesophagus	0.14mm long	0.20mm long	0.21-0.25mm long
Intestinal caeca	Relatively simple. 8mm long	Looped Twice length of body(?)	Looped. Twice length of body.

The excretory system in Paragonimus Kellicotti is relatively simple. The excretory pore is of such size (0.050mm) that its position may be determined with the unaided eye under favorable conditions. It lies on the dorsal surface 0.2-0.225mm from the posterior extremity, and opens into a small canal about 0.062mm in diameter and 0.225mm long. A cuticular layer lines the canal, surrounding which is a well developed muscular layer. The canal passes directly forward, terminating abruptly approximately midway between the dorsal and ventral margins of the large excretory sinus which lies in the middle axis of the body. The greatest dimension of the sinus is in the dorso-ventral direction, approaching the body surfaces very closely, to within 0.15mm dorsally and 0.315mm ventrally behind the acetabulum. It extends anteriorly to within 0.45mm of the branching of the oesophagus, reaching its termination here gradually, and finally disappearing nearer the dorsal than the ventral surface. As already stated, the sinus lies in the median axis, but in the region of the uterus, which lies on the left side somewhat anterior to the middle of the body, it shows a distinct bending to the right. Its median position is again resumed beyond the uterus.

The sinus has a distinct lining, as have also its main branches. These branches are not conspicuous along the sides of the sinus in the posterior region, but anteriorly in front of the acetabulum, a number are given off. These branches in all probability connect up with the large stellate flame cells that are distributed throughout the body.

The excretory system of Paragonimus Westermanii consists of the large central reservoir, and its numerous lateral branches. In general such a condition exists in Paragonimus Kingeri and in Paragonimus Kellicotti. Considered more closely, however, there are also here certain

differences. The large central reservoir in Paragonimus Westermanii according to Kerbert lies along the median line in the posterior part of the body, and opens to the exterior at the posterior pole through a circular opening. Kerbert does not mention the presence of a short duct between the sinus proper and the excretory pore. This may be an error in observation due to inaccurate methods of technic. The appearance of the reservoir in Paragonimus Westermanii is in most cases, according to Kerbert, that of a longitudinal or pear-shaped tube, but may also be a spherical bladder. The latter observation was made upon fresh material. The excretory bladder in Paragonimus Ringeri according to Leuckart is a very much elongated, narrow sinus with its greatest dimension in the dorso-ventral direction. It is not confined to the posterior part of the body, but extends anteriorly to within a very short distance behind the bifurcation of the oesophagus. A short canal leads from the posterior extremity of the sinus to the excretory pore. This opening has a diameter of 0.05mm and according to Leuckart lies on the ventral surface in Paragonimus Ringeri. Professor Ward's specimens are slightly distorted, but seem to indicate this relation. In Paragonimus Kellicotti the excretory pore appears on the dorsal surface in about the same relation with the posterior extremity.

		P. Westermanii	P. Ringeri	P. Kellicotti
Excretory pore		Posterior pole	Ventrum, a short distance from the posterior extremity	Dorsum, a short distance from the posterior extremity
Excretory canal		?	Present	Present
Sinus	Shape	Long, pear-shaped tube or spherical bladder	Elongated narrow tube	Elongated narrow tube
	Position	Median line, posterior part of body	Median axis, anteriorly nearly to oesophagus	Median axis, anteriorly nearly to oesophagus.

With the exception of the vitellaria, the reptoductive system of Paragonimus Kellicotti is confined to a little more than the middle third of the body. The genital pore lies about 0.078-0.104mm behind the acetabulum, usually a little to one side of the median line. This affords the opening for the genital cloaca. To the right, and near the dorsal wall is the ovary, while on the left nearer the ventral surface appears the highly coiled uterus. At about the level of the ovary, but in the median line lies the shell gland, from which the proximal portion of the uterus emerges.

The genital cloaca is a short flask-shaped structure only 0.20-0.21mm long. It opens to the surface of the body through the genital pore and furnishes the connection between the male and the female reproductive systems. The wall of this structure consists of an inner homogeneous or granular layer, and an outer muscular which is essentially of the circular type. The terminal portion of the vas deferens narrows to a small tube, the ductus ejaculatorius, which enters the genital cloaca in about the middle region. The metraterm, or terminal portion of the uterus, enters near the base of the cloaca, usually on the side opposite to the opening of the vas deferens. Cirrus and cirrus pouch are absent.

The male reproductive system of Paragonimus Kellicotti consists essentially of the two testes that occupy the third quarter of the body, and the two vasa efferentia leading from these. The vasa efferentia unite near the dorsal margin of the excretory sinus to form the vas deferens,

The two testes lie on each side of the body, and occupy nearly the entire space between the intestinal caeca and the excretory sinus. The central portion of each testis lies approximately midway between the

dorsal and ventral body surfaces. Their symmetrical arrangement is disturbed in as much as the right testis is slightly posteriad to the left. In this particular there is a variation, for in one specimen the right testis seemed to lie anterior to the left. Very long slender lobes extend from the upper margin of the testes. These are usually two in number, and after their origin they arch upward and backward through the parenchymatous tissue. The terminal end of the lobes is enlarged, and frequently divided into lobules. Other lobes, three to four in number, extend from the ventral margin of the testes. These are not as long as those given off from the dorsal margin, although their terminal ends are also enlarged, and almost always show two or more lobules. (Pl. I fig 7, 12).

The vasa efferentia which are two in number, corresponding to each of the testes, have a diameter of 0.026-0.046mm at their point of origin. They spring from the middle portion of the testes at about the same dorso-ventral level, although the right one is a little longer than the left. Each after its origin ascends gradually, and at the upper margin of the excretory sinus they lie parallel with each other. At this point the right one crosses to the left side, and after both descend somewhat, they unite slightly to the left of the sinus at a level just below the shell gland and vertically above the genital pore to form the vas deferens.

The vas deferens is a relatively large duct, 0.062-0.10mm in diameter. It drops to the ventral surface, arching toward the anterior extremity. Keeping to the left side it approaches the acetabulum partly surrounded by the coils of the uterus. Then diresting its course posteriad it nears the ventral surface, finally to terminate in the genital cloaca. During its passage to the genital cloaca, the vas deferens shows

a number of characteristic features. Just at the posterior margin of the acetabulum it suddenly narrows to a small tube which becomes even smaller as the genital cloaca is approached. This portion of the vas deferens is heavily musculatured, probably functioning as a ductus ejaculatorius. Surrounding the vas deferens in the region where it suddenly narrows is a mass of glandular cells. These gradually disappear toward the genital cloaca, and probably constitute the prostate gland. The inner cuticular lining of the genital cloaca is continued into the ejaculatory duct, but farther on the nuclei of cells appear, although the lining retains its granular structure. A muscular layer consisting of circular fibers completes the wall of the vas deferens.

The testes of Paragonimus Westermanii lie near the dorsal side of the body, behind the transverse vitelline ducts (Kerbert). In structure they show five to six lobes. The right testis lies close behind the transverse vitelline ducts, while the left one is found nearer the posterior end of the body. For this reason it is possible to differentiate between an anterior right, and a posterior left testis (Pl II fig.17) The position and relation of the testes is different in Paragonimus Kingeri according to Leuckart. Here they lie nearly symmetrical, well towards the posterior extremity of the body. They are not confined to the dorsal region (Leuckart), but occupy the greatest part of the space between the intestinal caeca and the excretory sinus. In dorso-ventral dimension they have considerable extent. Comparing the figures given for Paragonimus Westermanii by Kerbert, and for Paragonimus Kingeri by Leuckart, a clear difference in form is apparent. Those of Paragonimus Westermanii are more dense, and the lobes regular in form, while those of Paragonimus Kingeri are diffuse, and irregularly lobed.

Kerbert records that the vasa efferentia in Paragonimus Westermanii pursue a dorsal course, arching over the transverse vitelline ducts, and after several loopings approach the ventral surface to unite into a common seminal vesicle which is continued into a short ductus ejaculatorius. The vasa efferentia in Paragonimus Fingeri according to Leuckart pursue no such a course, in fact neither one arches over the transverse vitelline ducts, while the left one drops gradually to the ventral surface without ascending dorsally. In addition, the vasa efferentia in Paragonimus Westermanii are more slender, being 0.01-0.016mm in diameter (Kerbert), while in Paragonimus Fingeri they are 0.045-0.1mm in diameter (Leuckart).

The vasa efferentia in Paragonimus Fingeri, according to Leuckart, do not pursue a symmetrical course. The right one rises gradually toward the outer margin of the shell gland, close under the transverse vitelline ducts, then drops almost perpendicularly approaching at the same time the median line, and under the ventral margin of the shell gland unites with the vas efferens of the opposite side. This one pursues a much simpler course, for it does not approach the dorsal surface, but directed downwards toward the anterior extremity and medially, it crosses the margin of the excretory sinus relatively far forward. Continuing its ventral and median direction it is finally continuous with the common duct.

This portion of Leuckart's description is not clear, and might be construed in either of two ways; (1) that the union of the vasa efferentia takes place ventrally to the excretory sinus, or (2) that it occurs dorsal to the sinus. The figure in the text illustrating this point shows the first relation, while the description might be understood as indicating either. Among the specimens of Paragonimus Finger in Professor Ward's collection there was one which had been broken just behind the genital pore.

The anterior portion of this parasite was sectioned, and the relation of the vasa efferentia studied. In this specimen the ducts unite dorsal to the excretory sinus. The vas deferens drops ventrally surrounded in part by the coils of the uterus. That there is opportunity for certain variations in the relation of the vasa efferentia is readily understood from the fact that with continued growth of the parasite the uterus becomes engorged with ova, finally pressing nearby structures out of their original relationships.

The vitellaria of Paragonimus Kellicotti are very extensively developed. Not only do they cover the parasite laterally, but also extend over the dorsal surface of the body, meeting both anteriorly and posteriorly, leaving but a very narrow space in the median line which becomes broader just in front of the transverse vitelline ducts, finally to disappear entirely toward each extremity. Around the oral sucker there is also a free space. The ventral surface presents a relation very similar to the dorsal except that on this surface the vitellaria do not meet near the anterior sucker, and correspondingly do not approach the median line so closely. The product of the vitelline glands is gathered up by many small ducts which gradually unite on each side to form two main trunks, one arising in the anterior region, and the other in the posterior region. These converge toward a point a small distance in front of the middle of the body, and unite here to form the large dorsally located transverse vitelline ducts.

This distribution of the vitellaria contrasts with the condition in Paragonimus Westermanii, and Paragonimus Pingeri. In these species a considerable space in the median dorsal and ventral line is not covered by vitellaria. In other words, the vitellaria on the dorsal surface of

Paragonimus Kellicotti approach more closely the median line than do those of Paragonimus Westermanii and Paragonimus Ringeri, and consequently are more extensive in their development. The relation on the ventral surface is very similar. The vitellaria of Paragonimus Kellicotti approach the median line more closely than those of Paragonimus Westermanii and Paragonimus Ringeri, but at the same time not so far as they do on the dorsal surface. (Pl. II figs 23-24).

The vitelline reservoir in Paragonimus Kellicotti is a pear-shaped structure arising at the point of union of the transverse vitelline ducts. These ducts narrow considerably before terminating in the vitelline receptacle. At this point the reservoir has its widest dimension, and dropping ventrally for a short distance and at the same time becoming narrower, it directs its course anteriorly. Having reached a plane slightly below the shell gland, it changes its course, and proceeds slightly upward until about the level of the junction of Laurer's Canal and the oviduct. Here it turnes sharply to the right, and unites with the short canal formed by the union of these two ducts.

The transverse vitelline ducts in Paragonimus Westermanii according to Kerbert open directly into a large pear-shaped reservoir, 0.25mm broad and 0.4mm long. The gradually narrowing end of this becomes the canal which conveys the yolk material to the proximal portion of the female reproductive system. This condition closely typifies the relation in Paragonimus Kellicotti, but not as described by Leuckart in Paragonimus Ringeri. Here the two vitelline ducts unite to form a single canal, which drops ventrally a short distance, and then broadens out into a large flask-shaped reservoir 1.5mm long. (Pl. I fig. 21). From the median margin of the anterior extremity of this reservoir, and on the inner side of the

unpaired canal, a small duct arises and passes dorsally to unite with the duct formed by the junction of the oviduct and Laurer·s Canal.

The ovary in Paragonimus Kellicotti lies on the right side, close to the dorsal wall of the body. Only a small portion extends down far enough to lie along side of the excretory sinus. The transverse vitelline ducts bound this organ posteriorly.(Pl. I fig. 14). In relative size, the ovary is about as large as the testes, but not so diffuse. It presents a rather close form, and even though lobed, the lobes are heavy and do not extend so far from the main body of the organ as do those of the testes.

The oviduct is a short tube, at first very wide(0.36mm). It arises near the upper margin of the ovary, and from that portion which lies toward the median line. It soon narrows down to a very small tube, 0.018mm in diameter and about 0.13mm long. Just after its origin on the ovary, the wall of the oviduct becomes heavily musculatured. This portion of the canal is the oocapt. The oviduct rises slightly toward the dorsal surface, but drops again to about the plan at which it left the ovary. Here it unites with a small canal which comes from a large pocket (0.057mm in dia.) of Laurer·s Canal. The wall of the oviduct consists of the cellular lining as is described for the male reproductive system, and the outer circular muscle layer.

From the pocket in Laurer·s Canal there extends outward to the right a blind pouch, or seminal receptacle, about 0.195mm long and 0.052 mm in diameter. Laurer·s Canal makes its way from this pocket towards the dorsal surface. At first the Canal is relatively large, but soon narrows down to a small duct. It proceeds in a sinuous course, and terminates on the dorsal surface of the body in the region of the transverse vitelline ducts. The pocket and the seminal receptacle,as well as

the lower portion of Laurer·s Canal swarm with spermatozoa. The oviduct and Laurer·s Canal unite to form a tube about 0.031mm in diameter. This continues about 0.045mm when it receives the vitelline duct, and then widens to form the ootype. The ootype discharges into the proximal end of the uterus.

The ovary lies in the same body region in all three of these species. According to Kerbert the lower portion of Laurer·s Canal in Paragonimus Westermanii is provided with a seminal vesicle (Pl II fig.16). Leuckart, however, doubts the accuracy of this observation, since he did not find such a structure in Paragonimus Pingeri. A seminal receptacle is present in Paragonimus Kellicotti, and Kerbert not only records its presence in Paragonimus Westermanii, but also gives measurements. If this structure is not present in Paragonimus Pingeri, its absence may mark a difference in structure.

The shell gland as reported for Pingeri by Leuckart is a large organ, lying a little to the right of the median dorsal region of the body. It is 0.5mm thick and about 1mm long. This organ is also well developed in Paragonimus Kellicotti. It lies close to the dorsal wall, and is more or less oval in shape, although somewhat irregular in outline; 1mm long, 0.5mm thick, and 0.87mm broad. Kerbert records approximately the same relation in Paragonimus Westermanii, although the shell gland is somewhat smaller being 0.02-0.03mm long x 0.012-0.014mm broad. The shell gland surrounds the proximal portion of the uterus, as well as the terminal portions of those ducts which go to form this part of the female reproductive system. (Pl. I fig.15)

The uterus in a fully matured parasite is a very extensive coiled tube. As the ova accumulate the uterus becomes widely distended

so as to occupy nearly the entire lateral portion of this region of the parasite. The walls of the uterus are made up of a relatively thin cellular layer, and a well developed muscular layer consisting of circular fibers. Towards its terminal portion the uterus narrows down to form the metraterm. In this region the walls become heavily musculatured.

The relation of the uterine coils in Paragonimus Westermanii as indicated by Kerbert's sketch (Pl.II fig.17) is much simpler than is the condition in Paragonimus Fingeri and Paragonimus Kellicotti. In the former parasite the loops are open, and may be distinguished readily, but in the latter two forms they are close, and the entire organ presents a mass-like appearance. Of course, the stage in development is an important factor.

The ova of Paragonimus Kellicotti are elliptical in shape, about 0.083mm long × 0.055mm wide. The mucous exudate obtained from the bronchi and cysts of infected hog lungs was brought into glycerin jelly, and mounted within asphaltum rings. Similar preparations were made using the sputum obtained from an infected Korean in Chemulpo, Korea. These prpparations made possible a comparative study of the ova from the American and Asiatic parasites, or specifically from Paragonimus Kellicotti, and Paragonimus Fingeri.

The measurements were made using a ×2 ocular and a ×8 objective. Twenty eggs from each species were selected, care being taken to choose only such as were normal and perfect. The values obtained are;

Species	Length			Width		
	Aver. mm	Max. mm	Min. mm	Aver. mm	Max. mm	Min. mm
P. Kellicotti	0.083	0.0875	0.0775	0.0559	0.065	0.0525
P. Fingeri	0.0872	0.0970	0.0800	0.050C	0.055	0.0460

These dimensions were then used in constructing an ideal outline for the egg of each species, and in this way Fig 22 was obtained. From this may be seen that the eggs of Paragonimus Kellicotti are broader than those of Paragomimus Finger, and in this serirs averaged shorter in length. There is in addition a very characteristic difference in the non-operculated end of each. That of the ova of Paragonimus Kellicotti rounds off rather sharply with the production of a pointed extremity, while the non-operculated end of the Paragonimus Fingeri ova has a wider curve, giving the egg a more elliptical outline.

This series of measurements concluded the first stucy on the ova. Several months later sputum was obtained from a Korean by Dr. M.M. Null of Seattle, Wash., and kindly forwarded to Professor Ward. In the laboratory examination three series of twenty eggs each and one series of ten eggs were made, These ova were measured under a ×2 ocular and a ×8 objective. The averages obtained are;

		Length = mm			Width = mm	
	Aver.	Max.	Min.	Aver.	Max.	Min.
Series I(20)	0.0812	0.0884	0.0754	0.0493	0.0546	0.0442
Series II(10)	0.0822	0.0884	0.0780	0.0499	0.0520	0.0468
Series III(20)	0.0806	0.0858	0.0780	0.049C	0.0546	0.0442
Series IV (20)	0.0813	0.0858	0.0780	0.0483	0.0520	0.0468
Total (70)	0.0812			0.0492		

The eggs were clearly of the Paragonimus type, but the question now arose

as to the species they represented. Were they from the Asiatic parasite, or were they from the American form? Comparison with the dimension of the Paragonimus Kellicotti ova showed a considerable difference in width, although in length they corresponded.

	Length	Width
Paragonimus Kellicotti	0.0830 mm	0.0559 mm
Unknown	0.0812 mm	0.0492 mm

There was also the added difference that the non-operculated end of these ova was not sharply rounded, but elliptical, a feature of considerable importance.

Making a comparison with the dimensions obtained in the study of the Paragonimus Pingeri ova a very striking similarity in width was shown, although in length they were somewhat shorter.

	Length	Width
Paragonimus Pinger	0.0872 mm	0.0506 mm
Unknown	0.0812 mm	0.0492 mm

In addition, the outline of the non-operculated end corresponded to the shape of Paragonimus Pingeri. This gave more evidence in favor of the Asiatic species. After careful consideration of these points of likeness and difference, it was reasonably certain to conclude that the unknown eggs were from Paragonimus Pingeri.

The point which this study brought out is that the variation in the length of these ova comes between rather wide limits, while the width variation is very small, in fact the latter dimension remains fairly constant. The variation in width in the last study embracing the four averages is only 0.0016 mm, while the difference between the average

width of the 70 eggs and the average obtained in the first study of 20 eggs is 0.0014mm. The maximum width among the 70 eggs is 0.0546 mm, a dimension reached by only two eggs. A width of 0.0520mm was found for eighteen, while the majority approximated 0.049-0.050mm.

These results indicate that the form and dimensions of the ova have some diagnostic value. However, my measurements do not agree with those quoted by Ward (1908) for the ova of the human lung fluke.

Musgrave	1907	0.057 mm in width	Philippine Islands.
Katsurada	1900	0.057 mm in width	Japan.
Mackenzie	1904	0.0552mm in width	America (Japanese).

This difference may either suggest still another species, or on the other hand merely indicates a normal variation. The evidence in favor of either view must ultimately come from a careful study of determined specimens.

A Report of Paragonimus Kellicotti in Cats from Wauwatosa, Wisconsin.

During the past three years I have observed lung fluke infection in four cats from Wauwatosa, Wisconsin. The first of these was found accidentally during an autopsy, while the next two were suspected, and the suspicions confirmed by post-mortem findings. The fourth infection was diagnosed by a microscopic examination of the excrement with the finding of the characteristic eggs.

The first of these lung fluke infections occurred in a full-grown female cat. Early in the spring of 1906 a litter of four kittens was found under an old lumber pile. The mother cat had given birth to the kittens, and later when disturbed had hidden them there. Three of these kittens were returned to the owner, while the fourth was raised as a family pet. The kitten grew to full maturity, and in July 1907 gave birth to two young, only one of which lived. This one was killed accidentally some time after. On March 25, 1908 her second litter of three kittens was born. It was noticed in the meantime that the mother cat was frequently siezed with attacks of coughing. Just when these began, I do not know. Finally we decided to dispose of her. On about Dec. 28, 1908 she was chloroformed, and out of curiosity an autopsy held. Upon opening the thorax the lungs showed five dark-colored nodules. Cutting into one of these two elongated, reddish-brown parasites were found. All of the cysts were opened, and from each two parasites removed. The parasites were sent to Professor Ward, then at Lincoln, Neb., who identified them as lung flukes of the species Paragonimus Kellicotti. The kittens of this cat had in the meantime become full grown. Of the original three only two

were still in the neighborhood. Both of these developed a cough very similar to that which the mother cat had shown, One was shipped to Dr. Agnew of Evanston, Ill. where it was placed under somewhat limited confinement, and the course of the disease watched. At this time the presence of the lung fluke was only suspected. The cat was kept at Evanston from about the first of February 1909 until the first of November of the same year, when it suddenly died. An autopsy was held, and in the left lung an elongated cyst was found. Three adult parasites were removed from this cyst. The right lung was entirely free.

Upon making a short visit home at Easter 1909, I was told that the neighbors who had the other kitten wished to dispose of her because it coughed so much. Arrangements were made to hold the autopsy at the Milwaukee County Hospital in order to demonstrate the lung fluke infection in the presence of the internes. The investigation was made, and in the base of each lung a cyst containing two parasites was found. Unfortunately, two of these were destroyed by subsequent treatment with reagents, and the remaining two lost.

The fourth infection is very interesting because it occurred in a cat entirely unrelated to those just described, and in fact about two miles away from where the others had been found. This cat was a family pet, and the owner had become so attached to it that I experienced considerable difficulty in convincing him that the animal was a menace to his welfare and health. The cat coughed considerably, much as the other infected cats had done, but little confidence could be placed upon this observation. In the meantime sections were made of the lungs examined at the Milwaukee County Hospital. These showed numerous, rather large, yellowish eggs caught in the tissues. Professor Ward upon hearing of this suspected cat instructed me to examine the sputum or excrement for eggs. The cat

was placed at once under such conditions where the feces could be obtained easily. Using the eggs found in the lung tissue as standard it was not difficult to determine the presence of the lung fluke in this cat.

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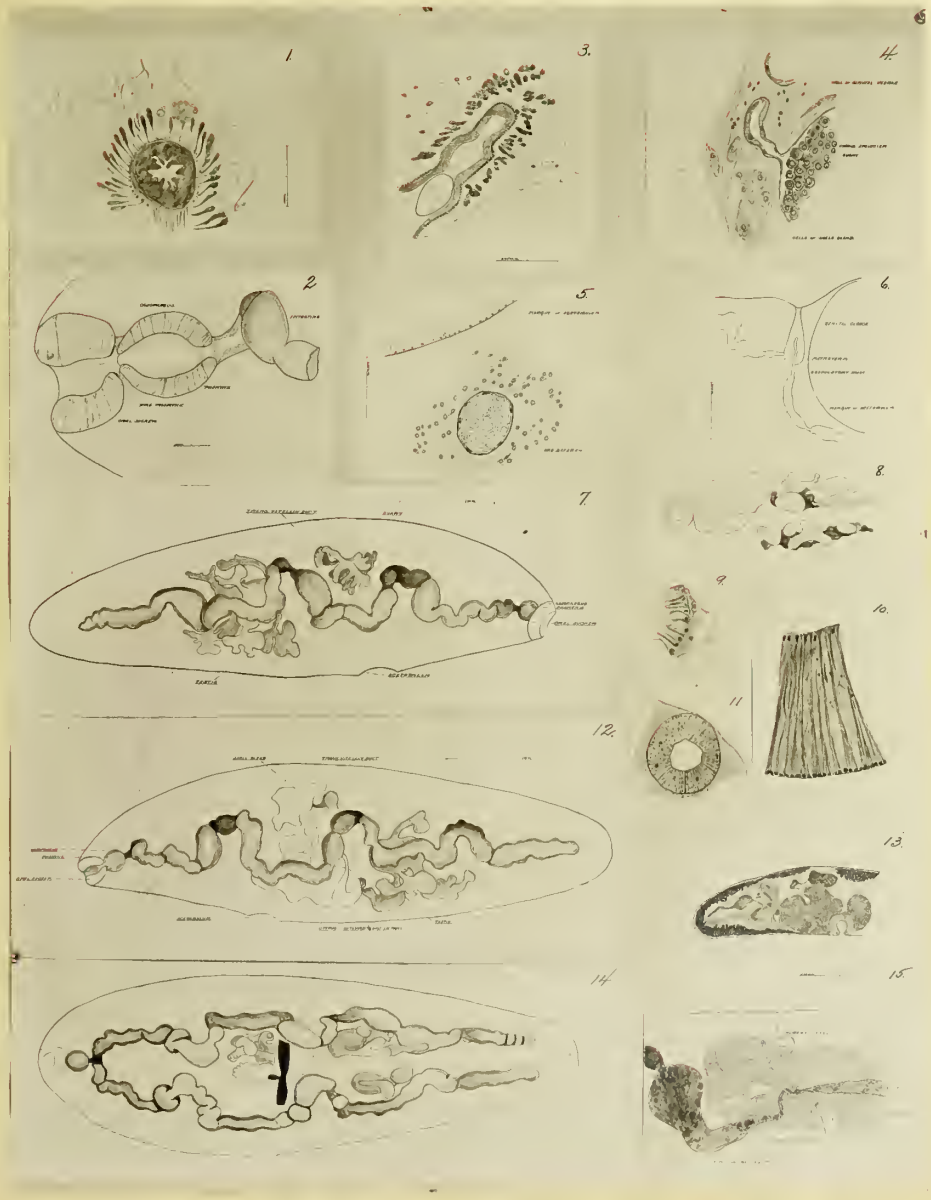
Explanation of Plates.

Plate I.

1. Cross section of Oesophagus.
2. Sagittal section through the oral sucker, pharynx, and oesophagus
3. Tangential section of metraterm.
4. Longitudinal section through oviduct.
5. Transverse section of vas deferens.
6. The relation of the metraterm and vas deferens at the genital cloaca.
7. Lateral view of the digestive system - right side.
8. Ventral view of the testes.
9. Epithelium of the intestinal wall.
10. and 11. Sections of the suckers.
12. Lateral view of the digestive system - left side.
13. Sagittal view of the posterior half of the body.
14. Dorsal view of the digestive system.
15. Sagittal section taken in the region of the shell gland.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Explanation of Plates.

Plate II.

16. Kerbert·s sketch showing the relation of the ovary, oviduct, Laurer·s Canal, vitelline reservoir and duct, and the shell gland in Paragonimus Westermanii.
17. Kerbert·s sketch of Paragonimus Westermanii.
18. Kerbert·s sketch of the sucker, pharynx, and oesophagus in Paragonimus Westermanii.
19. Sketch of flame cell.
20. Cross section of Paragonimus Kellicotti.
21. Cross section of Paragonimus Pingeri by Leuckart (diagrammatic)
22. Ideal sketch of the ova of Paragonimus Kellicotti and Paragonimus Pingeri.
23. Paragonimus Kellicotti.
24. Paragonimus Westermanii.
25. and 26. Cuticula of Paragonimus Kellicotti.
27. Spines of Paragonimus Kellicotti. (Hog)
28. Spines of Paragonimus Westermanii.
29. Spines of Paragonimus Pingeri.
30. Spines of Paragonimus Kellicotti. (Cat)
31.- 33. Spines on the ventral surface of Paragonimus Kellicotti.
34.- 39. Spines on the dorsal surface of Paragonimus Kellicotti.